ART. V.—*Notes on the Diabase Rocks of the Buchan District.*

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INTRODUCTION.

IN papers previously published in the Reports of Progress of the Geological Survey of Victoria,* on the Devonian rocks of North Gippsland, I gave some particulars as to those formations which collectively constitute, at Buchan, the Middle Devonian group, and whose geological age is determined by the characteristic marine fossils of the Buchan limestones.

In the last-published communication on this subject† I desired to describe and to bring into relation with each other the members of that group of rocks which I provisionally termed the Buchan Beds. I was led to make that more special examination by certain doubtful features which my previous more general examination had shown, and this again brought other appearances into view which required further elucidation. It even then remained uncertain whether certain dark-coloured basic igneous rocks at Back Creek and the Murendel River were intrusive into the Buchan Beds, or were older than some of them, and therefore contemporaneous members of the group.

I was not able at the time to completely satisfy myself on this point, but I inclined to regard them as being intrusive, and therefore younger than the whole of the Buchan Beds. Since then I have had an opportunity of examining this group of beds in detail over a wider area.

The following notes are the result of that examination, both as to the localities themselves in the field, and subsequently of the rock samples I then collected.

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* *Report of Progress of the Geological Survey of Victoria*, Parts III. and V.
† Same, Part V., p. 117.

Before entering upon details a few observations may be admissible upon the physical features of the district wherein the Diabase rocks occur.

Physical Geography of the District.

That part of the district which is dealt with in this paper lies between the Buchan and Snowy Rivers, and immediately within the angle formed by their junction. The area may indeed be imagined as a rudely equilateral triangle, across the base of which extends the diagram section accompanying these notes, while the apex is approximately marked by the junction of the rivers. The country is mountainous, but it is lower in elevation than the tracts surrounding it. It is less rugged in outline, and it possesses a better soil and is more richly grassed than the felsitic areas amongst which it lies. This more favoured character is due to the preponderance in it of the Buchan limestones, and of the Diabase rocks which are the special subject of this paper.

The characters of the two rivers, the Snowy and the Buchan, which bound two sides of the area, differ considerably. The former rises on the great table land of Maneroo, and descends rapidly near the boundary line of the colony through a deep rocky valley, excavated into indurated Lower Silurian formations, and it thenceforward flows in a deep and, generally speaking, a barren valley towards the sea. The rocks in which this part of the valley has been excavated are mainly varieties of intrusive granites, or of kindred rocks of an acid character, such as felsites. More rarely there occur tracts of Silurian sediments in a greatly inclined and indurated condition. In that part of the valley which lies to the east of Buchan there are small areas of limestone which have been preserved by having been let down by extensive and often well-marked faults. Near the junction of the Buchan and Snowy Rivers there is a somewhat larger outlier than usual of these Buchan limestones, and associated with them is a still larger area of Diabase rocks. These latter are dealt with in these notes.

The settlement of Maneroo, the consolidation of the soil, and the grazing down of the thick coat of natural grasses by flocks and herds, the formation by stock of tracks and by man of roads, has, for the last twenty or thirty years, caused the rain falling on the great plateau to concentrate more and more rapidly in the main drainage channel. So

long as the pitch of the river bed remains but slight, as on the table lands, no very great changes have followed; but where the river bed descends rapidly, as does that of the Snowy into the valley lying within this colony, the changes produced have been enormous.

Early settlers with whom I have conversed assure me that these changes in the Snowy River valley date from the year 1852. Its condition in the year 1848, about where the boundary line of this colony crosses it, has been described to me by one of the early settlers, as follows:—The river was then from 60 to 70 yards across, between banks about three feet in height, and with a rocky and shingly bottom. The flats were from 100 yards to a quarter of a mile wide, and were luxuriantly covered with oat-grass. Here and there a big rock stuck out of the soil.

The river began first to cut its banks in the year of the great Gundagai flood (1852), and almost the whole of the soil was then carried away. Each subsequent flood has added to the change, the great flood of 1873 having even removed the soil in many places from the hill-sides for some thirty feet above the river level.

The present state of the valley within flood-marks may be described as being washed out to the bed, and being either bare rock or banks of sand, gravel, or boulders. I have myself observed that throughout the whole course of the river, from the boundary line to the low lands near the coast, there are now no trees growing within flood-marks. In consequence of all these changes the drainage area of the river is undergoing more or less accelerated degredation, and the swamps and lagoons at the Snowy River mouth are in process of being filled up.

The Buchan River rises in Victoria, in the Great Dividing Range, near the mountain known as the Cobboras. Throughout its course to Buchan it flows in narrow and wooded valleys, which are almost uninhabited, and but little stocked. It has, therefore, remained far more in its original state than has the Snowy River valley. Still, changes somewhat analogous have occurred, though to a less degree.

However much this rapid stripping of the alluvial soil from the valleys is to be regretted, as possibly pointing to a future general denudation of the hill sides and sloping ground of the drainage area, the immediate result has been to disclose innumerable natural sections of the formations, of the very greatest interest and value to the field geologist.

It may be said that the floods which, during the past ten years, have swept out the streams, in many cases to the bed rock, in the North Gippsland mountains, have opened up a storehouse of facts bearing upon some of the most interesting as well as difficult problems of petrography.

Description of the Rocks.

In the preceding paper on the Buchan Beds* I was led, from an examination of the much-altered olivine-bearing rocks at the Murendel River, to regard them as representing basalts, and I also regarded all the basic igneous rocks, both at the Murendel and Back Creek, as belonging to the same group. I now proceed to give the results obtained from a more complete and extended examination in the field, and a careful analytical examination of the samples I had collected.

The sketch section given here extends from Moore's Crossing, at the Snowy River, to a little west of the Murendel galena mine. The line of section and the Snowy and Buchan Rivers rudely represent an equilateral triangle, the junction of the rivers being at the apex. The length of the section is about three miles. In order to give as complete a view as possible of the various rock masses crossed, and also of their relations to each other, I have found it advisable to repeat some of the features given in a section at p. 131 in the previous paper.

The section commences on the eastern side of the Snowy River, at Moore's Crossing. At this place there is a somewhat larger outlier of the Buchan limestones than usual. On the western side, for some miles up and down the river, the principal rock is a dark-coloured (dark brown to nearly black) massive igneous rock. On the eastern side the limestones preponderate, and on the western side these igneous rocks. But on both sides there are numerous places where the contact of both rocks can be well observed. This dark-coloured igneous rock is evidently akin to that which, at the Back Creek, underlies the limestones, and also in that locality extends over much of the eastern side of the Buchan River. It decomposes into a moderately good soil, and it weathers into harsher and more rugged masses than is usual with the basalts and dolerites of Gippsland. This harsh character is

* Progress Report Geological Survey of Victoria, Part V., p. 117.

everywhere the same where I have observed these rocks. They are often slightly porphyritic, with felspar prisms. The following notes on this rock and its varieties, as observed above and below Moore's Crossing, will illustrate its physical and microscopic characters, and its relations to other rock-masses.

At the eastern end of the section the Snowy River flows over these igneous rocks, which, on the eastern bank, are immediately overlaid by the representatives of the Buchan limestones. I have described in the previous papers already quoted the contact of the Devonian limestones of Buchan, through passage beds, with the uppermost members of a series of felsitic beds, for which I suggested the name of Lower Buchan Beds. Here, however, we find that the marine limestones do not, as elsewhere, rest conformably upon the felsitic beds, but upon massive igneous rocks of a basic character.

It may be well, however, before speaking further of the mode of occurrence of these rocks at the Snowy River, to consider the results of the microscopic and chemical analyses to which I subjected the collected samples. It will then be possible to make a first step in advance—namely, to determine the class to which these basic igneous rocks belong.

I prepared thin slices from samples collected from six different localities. I selected a sample for chemical analysis which appeared to me to be but little altered, and, at the same time, fairly to represent the average character of the rock masses.

Microscopic Structure of the Rocks.

The structure of these rocks, as seen in thin slices under the microscope, is generally microporphyritic, and more rarely approaches porphyritic. The ground-mass usually contains, or is partly composed of, some almost colourless or slightly yellowish or brownish basis. I have found this to be in some cases microfelsitic.* The basis, where it is at all abundant, contains great numbers of minute dust-like particles. In places these particles coalesce so as to form long and narrow trichites, or often resemble a number of beads

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* Microfelsitic, *i.e.*, consisting of an aggregate of exceedingly minute crystalline particles. See *Zirkel. Mikroskopische Beschaffenheit der Mineralien und Gesteine*, p. 280; also *Rosenbusch Physiographie der Massigen Gesteine*, p. 65.

strung upon a thread. In places these trichites cross each other like a net-work. In a few cases I have observed that there are no trichites, but then these dust-like particles are diffused in numbers throughout the basis, which fills in the spaces in the crystalline ground-mass. The slices are in such cases very obscure. In rarer cases the basis contains very many rounded granules (sperulitic bodies) of a darker shade of brown than the basis. In such cases I have observed only a few thorn-like microliths, and none of the black dust so frequent in other examples.

Perhaps the most numerous components of the ground-mass are very minute prisms of felspar. In some cases these form a perfect net-work, separated by the basis, and enclosing the other constituents. In most, if not in all, instances these minute felspars seem to be twinned and to be triclinic.

The next most frequent component of the ground-mass is an ore of iron, either in irregular grains or in distinctly rectangular crystals. I believe these to be in almost if not all instances magnetite. At least such would be the case in the sample chosen for analysis, for in it I failed to obtain any titanic acid by special examinations. Still, titaniferous ores are not probably wholly absent, as I have occasionally observed hexagonal forms suggestive of them. Larger masses of black opaque iron ores fill in what probably represent the sites of former minerals, and there is often also a deposit in the ground-mass of ferric oxide (hæmatite), as well as ferric hydrate (brown iron ore). Finally, needles and prisms of apatite are very frequent in the ground-mass.

The porphyritic minerals are the following :—

Felspars.—All of these are triclinic. Their terminal planes are not, as a rule, well developed, and it is common to see them fractured, and the parts pushed aside. These felspars do not seem to have been the first constituents to crystallise, for they include small crystalline grains of augite, and have also been broken by crystals of the same. It is very common for these felspars to have their crystalline planes marked in the interior of the prisms by rows of rounded, oval, or ragged particles of what seems to have been glassy material.

The composition of these plagioclase felspars is, in almost all cases, by wide rather than narrow lamellæ. They are usually compounded according to the Albite law, sometimes according to the Carlsbad law, and in rare cases I have observed cross lamellæ which may be said to be interposed according to the Pericline law. It may be said that the

larger the porphyritic crystals are the less perfect is their form; and this imperfection arises not from incomplete crystallisation, but from the fracture of the crystals, or also from their partial subsequent fusion.

The inclusions are confined to exceedingly numerous rounded or ragged portions of glass or slag, less numerous colourless microliths, and apatite in prisms or needles. This latter varies in amount in different samples examined, as is also shown by the two analyses given in this paper.

The alterations to which these felspars have been subjected are of three kinds:—

(a). To finely granular or scaly aggregates, which have but a slight effect upon polarised light, and which may be kaolin.

(b). Rather minute aggregates of calcite.

(c). Aggregates of plates and minute prisms of some almost colourless or greenish minerals.

It is frequently the case that the cleavages and flaws in the felspars are lined with translucent red flakes of ferric oxide (hæmatite).

In order to determine, if possible, the position of these felspars in the series, I made observations on all the thin slices, in order to determine the angle formed by the plane of vibration, and the twin plane (edge $OP — \infty \breve{P} \infty$). The measurements which I recorded were those which gave equal or very nearly equal angles on each side of the twin plane, such measurements being in the zone $OP — \infty \bar{P} \infty$. These sections would, therefore, represent planes perpendicular to the edge $OP — \infty \breve{P} \infty$, and having inclinations between two limits—namely, the base (OP) and the macropinacoid ($OP — \infty \bar{P} \infty$). The lowest observed angles should, therefore, represent more or less correctly the former, and the highest angles the latter. Besides these sections of crystals which were twinned, there were others which were simple, and which, as they did not show either physical or optical features referable to orthoclase, may reasonably be considered as representing the plane $\infty \breve{P} \infty$ of the same triclinic felspar.

I therefore obtained three groups of measurements, which may be thus tabulated from six sets of observations:—

OP (001).		$\infty \bar{P} \infty$ (100).		$\infty \breve{P} \infty$ (010).
3° 30′	...	21° 0′	...	13° 0′
5° 0′	...	28° 0′	...	10° 30′
5° 30′	...	28° 0′	...	9° 30′
5° 30′	...	22° 30′	...	7° 30′
6° 0′	...	26° 0′	...	10° 0′
7° 0′	...	25° 0′	...	12° 0′

The investigations of Des Cloizeaux, and more recently those of Schuster,* show that the angles formed by the plane of vibration with the edge OP— $\infty \breve{P} \infty$ depend upon the position of the optic axial plane as well as upon the position in that plane of the optic axes themselves. As the last-quoted authority well puts it—"the plane of vibration moves round the edge PM."

It seems evident that the differences of position of the optic axial plane in the triclinic felspars is connected with variations in chemical composition according as the felspars contain, for instance, Na_2O, K_2O, CaO, singly or together, in variable proportions.†

According to Schuster's late observations the optical angles in oligoclase, andesine, and labradorite are as follows:—

OP (001).		$\infty \bar{P} \infty$ (100).		$\infty \breve{P} \infty$ (010).
+ 2° to + 1°	...	+ 18°	...	+ 3° to + 2°
− 1° to − 2°	...	...	...	− 4° to − 6°
− 4° to − 5°	...	− 30°	...	− 17°

Taking, therefore, in the list of measurements which I have given from these plagioclase felspars, the lowest for OP and the highest for $\infty \bar{P} \infty$ and $\infty \breve{P} \infty$ respectively, we have the following:—

OP (001).		$\infty \bar{P} \infty$ (100).		$\infty \breve{P} \infty$ (010).
3° 30′	...	28°	...	13°

On comparing this series of measurements with those quoted from Schuster, it suggests that the felspars to which they refer stand between a normal andesine and labradorite. But at the same time it must be borne in mind that, owing to the difficulties in the way of obtaining perfectly accurate

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* *Über die optische Orientirung der Plagioklase, Sitzungsberichte der Wiener Akademie*, Vol. lxxx., p. 1, July, 1879; also, *Neues Jahrbuch der Mineralogie*, 1880, Vol. ii., pt. 1, p. 8.

† Also, Ba O and, perhaps, Sr O.

and satisfactory angular measurements, these results cannot be regarded as being more than approximate.

The porphyritic mineral, next in importance to the felspars, occurs in almost or quite colourless crystals, whose cross sections show the usual outlines of augite, with a more or less marked prismatic cleavage of nearly 90°. Sections parallel to the axis c show traces of this prismatic cleavage, as also of a second cross cleavage. The angle of extinction in one of these sections I found to be 48° 50′. The terminal planes are not well developed in any of the sections, but in those instances which I could observe at all, suggested the base only. There was not any dichroism. The only inclusions I have observed are a very few crystals or granules of magnetite. The alterations are wholly to calcite, being easily removed by cold dilute acids. Perhaps half of the crystals, and especially the larger ones, are thus more or less altered. This mineral can scarcely be other than a magnesia-lime augite —that is, diopsid. The augite seems to have been one of the earliest crystallised minerals of this rock, for I find it included in the plagioclase felspars, and also causing their fracture. Its own often ragged and even cavernous outlines—being surrounded by ground-mass, and this eroded appearance not being the result of alteration—strongly suggest to me the action of a molten mass upon pre-existing crystals.

Associated with the augite is another pyroxenic mineral. It occurs, namely, in prisms of less dimensions than those of the former, and they are distributed through the ground-mass singly or in groups; and also filling in spaces between other porphyritic crystals. The cross sections of the prism are nearly rectangular. In its freshest condition it is colourless and but faintly fibrous. Its sections are not then dichroic, and it becomes obscured when the prismatic sides are parallel to the plane of polarisation of either of the crossed nicols. Alterations can be traced by the appearance of a fibrous structure, especially connected with separations across the prism. Its colour then becomes yellowish, and it is dichroic. In two instances I found that the ray vibrating parallel to c was faintly red in one case and yellowish brown in the other, while that vibrating perpendicular to c was nearly colourless and green respectively. In one instance, in which the prism was unusually well developed, having terminal planes perpendicular to the sides, the unaltered portions were colourless or faintly brownish yellow; transverse

separations were bordered by a bright green fibrous mineral, which extended irregularly into the colourless portions. This fibrous mineral was strongly dichroic: dark metallic green when the fibres were parallel to the polarising plane, and light green when they were perpendicular to it. This alteration I regard as some chloritic mineral. In further alterations the form of the prism remains; but when examined by polarised light it reacts faintly as an aggregate, and the flaws and separations are lined with brown iron ore.

The only inclusions which I have observed were small crystals and prisms of magnetite; but as these were invariably in the altered parts, and in connection with the chloritic mineral, I regard them as secondary products.

I think there cannot be any doubt that this orthorhombic mineral is enstatite, and that its alterations are, in the first place, to bastite, and finally to chlorite and to ores of iron.

Finally, the only remaining mineral to be noticed is apatite. Little, however, need be said concerning it. It occurs in its common prismatic form or as small needles. It is to be observed in the ground-mass, and especially in the larger plagioclase crystals. I have but rarely observed it in the pyroxenic minerals. It varies in amount in different samples of rock—being present in some cases in unusual abundance. The two analyses accompanying this paper illustrate this statement.

The secondary minerals to be noted are—First, calcite, which either forms pseudomorphs, generally after augite; less frequently replacing parts of the triclinic felspars; often filling space or diffused throughout the mass of the rock. It generally forms minute granular, but also crystalline, aggregates, in which the faint chromatic banded effects due to twinning, according to—½R, are often visible. Next to calcite are the alteration products after enstatite, of which I have spoken. Viridite, to apply a convenient term for otherwise undetermined chloritic minerals, is not so frequent in occurrence as might have been expected in rocks of the Diabase group of such great geological age. It occurs, however, more plentifully in some cases than in others; and I found it most commonly in slices, taken from places where the limestones rested upon the igneous rocks. Perhaps one of the secondary minerals which is most frequently met with in these rocks is agate, forming amygdules of from over an inch in diameter down to microscopic size. In thin

slices the concentric and radial structure is beautifully displayed. It is very common to find these amygdules bordered by a bright green granular mineral, which, in its inner margin, often extends in filaments or acicular prisms into the agate. This mineral polarises as an aggregate, and is not, I think, dichroic. The acicular crystals bordering it suggest epidote to me. This mineral is not attacked by digestion with hot sulphuric acid. I suspect that it may be an aggregate of silica, coloured by some pigment. I am at present unable to further define it. Finally, ferric oxide, as translucent plates, and ferric hydrate (brown iron ore), are found as alteration products in all parts of the rock-mass. Some of the magnetite is, doubtless, also of secondary origin.

The microscopic analysis of this rock shows that its original constituents have been plagioclase felspars, augite, and magnetite, with apatite, and, in almost all cases, a second pyroxenic mineral enstatite.

The felspars evidently greatly predominate in amount over the pyroxenic minerals. The entire absence of olivin places such a rock, it being of pretertiary age, at once, and in accordance with the classification I here follow, in the great Diabase group.* The presence of plagioclase and augite as porphyritic crystals in a ground-mass, containing more or less basis, limits its range to the porphyritic forms of Diabase; and the occurrence of the rhombic pyroxene enstatite again restricts it to a particular section. The rock, therefore, belongs, according to the microscopic examination, to the enstatite-bearing section of the Diabase porphyrites.

Having thus arrived at a conclusion, based upon microscopic examination and optical data, it will be well to see how far these are confirmed or contradicted by a quantitative chemical analysis and a discussion of the results.

The sample which I took for analysis was selected from near Moore's Crossing. It was of a blueish-black colour, and did not show any of the red tinge which in these rocks indicates alteration. It had a finely crystalline structure, and showed some porphyritic, but still minute, white felspar crystals, as also rarely small crystalline grains of pyrite.

I prepared several thin slices of this sample, cut perpendicularly to each other. I found it to be typical of the porphyritic rocks of the group. It was, on the whole, re-

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* Rosenbusch.—*Physiographie der Massigen Gesteine*, 1877.

markably fresh and unaltered. The porphyritic felspars were of the description which I have already given, and very clear and fresh; the principal thing to be noted being the deposit of ferric oxide in translucent red patches in the fractures and cleavages. The augite was colourless in short, stout crystals. It also occurred as clusters of irregular crystals, and I also observed grains included in plagioclase felspars. This augite was more or less converted into calcite; enstatite was numerous, as previously described, and almost the whole of it was converted into bastite (serpentine). Iron ores were precisely as mentioned before. The ground-mass consisted as usual of very numerous microscopic prisms of apparently triclinic felspars, of magnetite grains, and some basis, together with minute trichites and brown spherulitic bodies. In addition to the above, there were in all the slices, but more in some than in others, cavities filled by agate.

The analysis was carried out mainly by the ammonium fluoride process, FeO was determined by the bichromate process, and the alkalis by Smith's method; SiO_2—P_2O_5, CO_2, and H_2SO_4 were specially determined. As neither TiO_2 nor MnO were met with in the course of analysis, I made special examinations confirming their absence. The specific gravity of the sample was taken by means of Walker's steelyard balance.

	Per cent.	Molecules.	Ratio.		
SiO_2 ...	53·39 ...	177·98	Acids, less free SiO_2	=	3·822
Al_2O_3 ...	15·23 ...	29·57	R_2O_3	=	1·000
Fe_2O_3 ...	8·73 ...	10·91			
FeO ...	3·61 ...	10·03	RO	=	1·503
CaO ...	8·46 ...	30·20			
MgO ...	4·12 ...	20·60			
K_2O ...	1·84 ...	3·92	R_2O	=	·696
Na_2O ...	3·60 ...	11·61			
H_2O ...	1·14 ...	12·66			
CO_2 ...	·22 ...	1·00			
P_2O_5 ...	·16 ...	·23			
	100·50		Proportion of Acids to Bases (Indicative Ratio).		1·194 to 1

Hygroscopic moisture ... ·60
Pyrite ... ... ·16
Specific gravity ... 2·814

It is interesting, where practicable, to ascertain by calculation the approximate proportions in which the various minerals exist in the rocks examined. This may often be done with considerable certainty when the chemical analysis is supplemented by a microscopic examination, and more especially when the rock is crystalline or crystalline-granular. Owing, however, to the porphyritic character of this Diabase porphyrite, it is not easy to satisfactorily calculate the percentages of all the rock-forming minerals. A difficulty arises at once in regard to the porphyritic felspars and to the microscopic felspars in the ground-mass. Another difficulty also arises as to the constitution of the basis, and also of some of the alteration products.

The basis being small in amount, and probably of the same general constitution as the whole rock, though, perhaps, more acid, I have necessarily disregarded. I have also left out of view the slight traces of chloritic material associated with the altered enstatite. If the rhombic pyroxene, as I conclude from the microscopic examination, has been almost entirely converted into bastite, then, for the latter, the formula for serpentine will probably be applicable. The other alterations—calcite, ferric hydrate, and agate—offer no difficulties. On this basis I have attempted the calculation of the analysis into the rock-forming minerals.

The microscopic examination has shown that the augite is probably a magnesia-lime augite—in other words, diopsid, and, therefore, having the empirical formula (RO, SiO_2) where RO may be (FeO, MnO, CaO, or MgO). The rhombic enstatite would be the same. Not being, therefore, aluminous pyroxenes, it is not necessary to allot any of the alkalis to them. There remain, then, only the felspars and the basis to which K_2O and Na_2O are to be assigned; and I have already stated that I leave the basis out of view. Disregarding this, and the traces of viridite, the whole of the alkalis may be taken to calculate the potassa and soda felspars. The amount of lime felspar is given by the remainder of Al_2O_3 after providing for the potassa and soda felspars. The H_2O would probably be shared between the serpentinised enstatite and the ferric hydrate (limnite). The CO_2 and P_2O_5 give, of course, the amount of calcite and apatite respectively. The balance of CaO and the whole of $Mg.O$, with an equivalent number of molecules of SiO_2, indicate the augite ; and there should be some SiO_2 over as representing the small agate amygdules discovered in the miscroscopic

examination. Such a distribution of the rock-forming constituents—if the analysis be correct, and if I have correctly interpreted the microscopic data—should close without a remainder.

In making this calculation I have availed myself of a simple and effective method used by Professor Rosenbusch in his valuable work, "*Die Steiger Schiefer*," 1877. Not only is this method an extremely simple and effective one for calculating rock analyses, but it also affords an easy means of making a comparison of the ratios between the totals of acids and of bases which form the rock as a whole. To my mind it is preferable to the usual method of comparing the oxygen ratios. It affords what may be termed a mineralogical view of the composition of the rock instead of a merely chemical view. This is of great advantage when considering the probable proportions in which the various percentages are to be assigned to the constituent minerals. I have annexed this calculation to the analysis, and as it indicates a particular ratio for any one rock, and therefore a ratio within certain limits for a kindred group of rocks, I propose to speak of it shortly as the indicative ratio.

The method of calculation is based upon a comparative distribution of the constituent percentages calculated as molecules, between the minerals which are found to build up the rock, and the distribution is made in accordance with the most probable formula that can be assigned to the mineral.*

In calculating the molecular proportions of the percentages I have used the old atomic weights as giving simple numbers, and I have multiplied the results by 100, in order to bring them better under review.

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* I have made use of the formulæ given in Professor Groth's admirable "*Tabellarische übersicht der einfachen Mineralien*," Braunschweig, 1879.

Table A.—DIABASE-PORPHYRITE.

	Si. O_2.	Al_2. O_3.	Fe_2. O_3.	Fe. O.	Ca. O.	Mg. O.	K_2. O.	Na_2. O.	H_2. O.	C. O_2.	P_2.O_5.	Per cent.	Mole-cules.
	53·39	15·23	8·73	3·61	8·46	4·12	1·84	3·60	1·14	·22	·16	100·50	..
	177·98	29·57	10·91	10·03	30·20	20·60	3·92	11·61	12·67	1·00	·23	..	308·71
Calcite ..	..	..	..	..	1·00	..	..	..	..	1·00	..	·50	2·00
Apatite ..	..	..	..	..	·76	..	..	..	..	..	·23	·37	·99
Bastite ..	8·54	..	..	2·50	..	10·30	..	..	4·27	..	..	5·90	25·61
Limnite ..	..	..	2·80	..	..	..	..	..	8·40	..	..	3·00	11·20
Magnetite ..	..	..	7·53	7·53	..	..	..	..	..	..	..	8·73	15·06
Hæmatite ..	..	..	·58	..	..	..	..	..	..	..	..	·46	·58
Soda Felspar ..	69·66	11·61	..	..	..	..	..	11·61	..	..	..	30·45	92·88
Potassa Felspar .	23·52	3·92	..	..	..	..	3·92	..	..	..	..	10·92	31·36
Lime Felspar ..	28·08	14·04	..	..	14·04	..	..	..	..	..	..	19·58	56·16
Augite ..	24·70	..	..	..	14·40	10·30	..	..	..	..	..	13·50	49·40
Agate ..	23·48	..	..	..	..	..	..	..	..	..	..	7·04	23·48
Totals ..	177·98	29·57	10·91	10·03	30·20	20·60	3·92	11·61	12·67	1·00	·23	100·45	308·72

Assuming that the above calculation indicates the composition of this Diabase-porphyrite, a question remains as to the constitution of the felspars. This question, in fact, is—are the potassa, soda, and lime felspars associated together, or do they occur singly in this rock? Keeping in view Tschermak's theory of the felspars, there are, I think, three alternatives.

1. The potassa, soda, and lime felspars may be combined as a triclinic felspar, which occurs both as porphyritic and as microscopic crystals. This alternative is not, it seems to me, at all probable, for if the three are combined in a triclinic form, the potassa felspar would, I think, be most likely to be associated with the soda felspar as a potassa-bearing albite, which would then, in combining with the lime felspar, be in the proportion of albite 2·21 to anorthite 1·0—in other words, an oligoclase.

2. The potassa felspar may be in the ground-mass as orthoclase. The microscopic observations, that all the felspars in the ground-mass appear to be triclinic, negative this alternative.

3. The final alternative is that in the miscroscopic felspars, the potassa felspar and the soda felspar form together a potassa-bearing albite. For if the porphyritic plagioclase is taken in accordance with the microscopic data to be andesine, and of the normal constitution—namely, albite 1·0 to anorthite 1·0—then there remain for the microscopic felspars, soda felspar and potassa felspar in the proportions of 1·17 to 1·0. A felspar of such a composition is not improbable, although, judging from the analysis given by Rammelsberg, Dana, and other authorities, it might be expected to be monoclinic rather than triclinic. Yet the late researches of Fouqué* show that in the lavas of Santorin the porphyritic felspars are more basic than the microscopic prisms of felspar in the ground-mass, and that, moreover, the felspars have crystallised in the order of basisity. In the lavas of Georgios, where the porphyritic crystals were labradorite, or even anorthite, the numerous minute felspars in the ground-mass were albite, with perhaps a little oligoclase. It is noteworthy that in the analysis given of the albite, there is 1·33 per cent. of potassa evidently isomorphic in the compound with soda, while in the porphyritic crystals there is but ·08 per cent.

* Fouqué.—*Santorin et ses Eruptions*, Paris, 1879.

Some additional support is afforded to the third alternative by observations which I have made as to the results of digestion of thin slices of the Diabase porphyrite in concentrated hydrochloric, and for periods varying from twenty-four hours to a week. The porphyritic felspars were only slightly affected, even after the longer period, being still tolerably clear and not having lost their characteristic polarisation. The microscopic felspars in the ground-mass seemed to be absolutely unaffected by this treatment. Although not much reliance can be placed upon such experiments, in so far as they may be supposed to indicate the variety of felspar present, yet in this case it is evident that a difference exists between the porphyritic and microscopic felspars. The latter being not all affected are doubtless nearer to albite than the former.

It seems to me, therefore, on these grounds, that the third alternative agrees best with the data before me, and that the porphyritic felspars may be regarded as andesine, and the microscopic felspars as albite, in which the potassa felspar in its triclinic form is isomorphuous with the soda felspar. The constitution of a nominal andesine is albite 1·0 to anorthite 1·0 ; but here the optical measurements suggest an andesine, say, of albite 1·0 to anorthite 1·2 or more. In this discrepancy I incline, considering the difficulties in the way of obtaining satisfactory optical measurements, to give most weight to considerations drawn from the chemical analysis.

Supported by the foregoing arguments the following may be taken as the composition of the Diabase porphyrite of the Snowy River. The secondary ores of iron are calculated as magnetite, and the bastite as enstatite.

		Per cent.		Molecules.
Felspars	...	60·95	...	180·40
Augite	...	13·50	...	75·00
Enstatite	...	6·80		
Magnetite	...	10·62	...	18·32
Apatite	...	·37	...	·99

or felspar, pyroxene, magnetite, in the proportion of nearly 10.-4.-1. This shows the great preponderance of the felspars over pyroxene, which is one of the characteristics of Diabase porphyrite.

In order to compare this rock with others of the Diabase group, I have calculated twenty-eight analyses, as given in

the various works at hand.* I find in them the indicative ratio to lie between the following extremes:—

Diabase (11 analyses)	...	1·00 — 1·00 to 1·23—1·00
Augit porphyr (11 analyses)...		1·00 — 1·00 to 1·13—1·00
Labrador porphyr (6 analyses)		1·24 — 1·00 to 1·81—1·00

In these calculations there is, however, this difficulty, that there is no means of knowing whether some of the silica is not free, as in the rock I have described; nor does it seem that in all, or even most, cases regard has been paid to the presence or absence of CO_2 or P_2O_5, nor, the combined H_2O. The results are, therefore, only approximate, but they may possibly serve to roughly define the limits of the groups. Such being the case, then, this Diabase porphyrite, having the indicative ratio of 1·194 to 1·000, clearly stands at the end of the Diabase series and at the commencement of those porphyritic Diabase rocks which have been called "Labrador porphyr." If, as is probably the case in some of the analyses which I have calculated, all the silica, whether *combined* or *free*, were taken into account, then the indicative ratio would rise to 1·384 to 1·000, which would bring this rock well into the "Labrador porphyr" series. Having thus discussed at length the composition and structure of the Diabase porphyrite, I now proceed to show the position it holds in the series of formations amongst which it occurs.

A mile or thereabouts up the Snowy River from Moore's Crossing, and on the eastern side, there is an excellent example of the contact of the Diabase porphyrite with the Buchan limestones. The details of the various beds, which I now give, commence with the lowest rock visible in the river bed.

1. Massive Diabase porphyrite forming the river bed. In places it contains amygdules (agate, chalcedony), and also veins and small masses composed of a crystalline aggregate of quartz and epidote. A thin slice examined under the microscope showed the following particulars:—

The structure is micro-porphyritic. The ground-mass is composed of—(*a*) a colourless basis full of very numerous minute black dust-like particles, either scattered singly or in groups, or arranged linearly; (*b*) minute felspar prisms (triclinic ?); some of the minute felspar prisms have sharply defined outlines, while in others the planes are studded with

* Amongst others, Bischoff, *Lehrbuch*, &c., 2nd edition, 1864; Zirkel, *Lehrbuch*, &c., 1866; *Neues Jahrbuch für Mineralogie*, &c.

minute black granules, and are therefore irregular; (*c*) very numerous granules and crystals of magnetite; (*d*) very numerous prisms and needles of apatite.

In this ground-mass are:—

Triclinic felspars, most of which are compounded of rather wide lamellæ. One crystal is, however, very compound (albite law), the lamellæ being very narrow. Some few have no striations. The optical angles measured were—

$0P\ (001)$.		$\infty \breve{P} \infty\ (010)$.		$\infty \bar{P} \infty\ (100)$.
$3° 30'$	...	$13°$	...	$21°$

Enstatite very plentiful in prismatic forms of smaller size than usual. Alteration has so far proceeded that but little remains of even the chloritic minerals. The prisms are all dull, rather opaque and cloudy, with flaws and cracks lined with iron ores.

Augite.—In less amount than usual, but otherwise similar in character, and alterations to the instances described already.

Magnetite.—A few large rectangular crystals.

The principal alteration products are enstatite to chlorite, and some of the felspars to aggregates of colourless or slightly yellow doubly refracting flakes, and of magnetite to ferric hydrate. Flakes of viridite are also numerous in some few of the felspar crystals.

2. A coarse breccia of fragments of No. 1.

3. Vesicular Diabase porphyrite. This is about fifteen feet in thickness. A thin slice showed that it consists of a ground-mass composed of—(*a*) yellowish, slightly micro-felsitic basis, (*b*) brown translucent to opaque spherulitic bodies (these are so numerous as to make the ground-mass very opaque), (*c*) many minute felspar prisms, (*d*) magnetite grains or crystals, (*e*) a few needles of apatite, (*f*) a few black thorn-like microliths. In this ground-mass are:—

Plagioclase felspars.—These are so much altered that the striations are barely perceptible. *Augite* in colourless, short, stout prisms, some of which are almost wholly converted into calcite. Beside the calcite alterations, I observed others which I believe to be epidote.

Enstatite numerous, but smaller in size than the monoclinic pyroxene. It is wholly converted into some form of viridite. The vesicles in this rock are filled by agate amygdules, most of which are more or less bordered with the minute bright green aggregate which I have before mentioned.

4. Purple to reddish indurated mud. The lower part of this bed is full of large rounded boulders of No. 3. It is three feet in thickness.

5. A fragmental bed, three feet thick. The fragments are subangular, and under 5 inches in diameter. They all seem to be varieties of felsite.

6. Purple indurated mud, two feet thick.

7. Coarse breccia conglomerate. The fragments under six inches diameter and of varieties of felsites, white to purple in colour, or banded in different shades of colour. This bed is four feet thick, and weathers very rapidly.

8. Yellowish brown clayey material, two feet in thickness.

9. A fragmental bed, six feet in thickness. The fragments under three inches diameter. A slice taken from a portion of the finer-grained materials showed them to consist of angular and subangular pieces of felsite, of crystaline quartz grains, and of more or less broken crystals of orthoclase and of plagioclase, the former being most numerous. The fragments are cemented together by lesser fragments of the above, filled in throughout the inter-spaces by quartz and chalcedony.

10. An earthy bed enclosing felsite fragments. There are, however, two bands in it of more indurated material. This bed appears to have been a felsite ash or tufa, three feet thick.

11. Indurated materials, resembling No. 10, and two feet thick.

12. A yellow earthy bed, containing numerous fragments of felsite under one inch diameter.

13. A bed a foot thick of minute fragments, resembling an ash or tufa.

14. Grey compact limestones, dipping W, at 15°.

The total thickness of beds is about 46 feet; and Nos. 4 to 13 conform in general dip to No. 14.

This section shows clearly that the limestones have been laid down upon the Diabase porphyrites and on the passage beds connected with their abraded surface. It is also evident that at the time the sediments were formed part of the felsitic materials resembled a volcanic ash. The vesicular nature of the upper surface of the Diabase porphyrite also points to its having probably been a lava; and looked at by the light of evidence furnished by the natural sections to be seen in the district, it was most likely poured out on the coast line of a sinking volcanic land.

In tracing down the river from this point to its junction

with the Buchan, I made further observations. I found the Diabase rocks near Moore's Crossing to be rough, massive, and dark coloured. They weather dark brown, and are often so much decomposed as to be well described by the old name of "claystone porphyry." Further down the river they are very vesicular or amygdaloidal, or again, crystalline or microporphyritic. These rocks generally are traversed in all directions by veins of calcite and of red jasper, which also occur singly or together in geodes. In one place I observed appearances strongly suggestive of bedding; but the alterations in the rock were there so great that I was not able to determine this point to my satisfaction.

As the Buchan limestones have been generally denuded from these rocks along the river, the traces of their former existence are only observable in the extensive alterations which their contact with the igneous rocks has given rise to. The reactions have, however, been clearly subsequent to the consolidation of the Diabase rocks, and are, therefore, not to be confounded with ordinary "contact effects."

At about forty chains distance from the junction of the two rivers a change of rocks is evidenced by the different surface features, and an alteration in the nature of the soil, and the character of the vegetation. At the junction itself the rocks can be seen, and it then becomes apparent that the formation is one of the areas of Lower paleozoic (silurian ?) mudstones and sandstones in a greatly altered condition. The evidences of folding and contortion are very strong, and the rocks strikingly resemble some of the forms of metamorphic contact schists. Their present position alongside of the Buchan beds must be due to faulting, as they are highly inclined, whereas the former are comparatively horizontal. One sample examined under the microscope showed me the familiar appearance of a metamorphic contact schist. It consisted of fragments of quartz and felspars, set in a paste (mud) which had been converted into micaceous substances. Another sample of one of the most contorted varieties I found to be almost entirely mica—some of the larger flakes being evidently muscovite.

On leaving Moore's Crossing the line of section follows throughout the direction of the track, leading thence to Buchan. The Diabase porphyrites continue from the river to near the summit of the range, where come in felsitic rocks having the usual appearance of those near the Murendel River. These continue along the track to the Murendel River, but their continuity is broken in three

places at least by masses or wide bands of a dark-coloured basic rock, more finely crystalline than those I have just described. The section terminates at a high hill of massive felsite on the western side of the Murendel River. This hill appears to have been an original protuberance round which the Middle Devonian marine limestones have been laid down, and which still enclose it on three sides. Immediately to the south of this hill Buchan limestones have either been originally laid down upon, or have been broken through by the olivine bearing rocks, in which the adit of the Murendel-south Lead Mine was driven. I have referred to these rocks in a former paper.* I was then inclined to regard these olivine bearing rocks and the intrusive dyke-like masses beyond the Murendel mine as being, in fact, the same. I now propose to add some further particulars resulting from more recent investigations. My remarks refer now to the dyke-like masses near the Murendel mine, and along the track, as shown in the section accompanying this paper. The extreme freshness of appearance of this fine-grained rock, and its occurrence as an intrusive dyke of considerable size in the Lower Buchan beds might lead to the suspicion that it is comparatively recent in geological age as compared with the Diabase porphyrite of the Snowy River. It even bears some resemblance, when examined in thin slices, to some of the miocene tertiary volcanic rocks of the Dargo High Plains. I hoped that by examining it carefully both by microscopic and chemical analysis, I might be able to form an opinion not only as to its position in the petrographical system, but even to hazard a conjecture as to its geological age. These data might then also bear upon the question whether the olivine-bearing rocks of Murendel south are intrusive or contemporaneous. I selected a sample for examination from the dyke-like mass crossed by the track immediately before reaching the Murendel mine.

The examination of several thin slices showed me that the rock is composed of a ground-mass consisting of :—

(*a*) A little pale, brownish yellow to almost colourless basis. In some slices this basis is almost absent.

(*b*) Minute felspar prisms in great numbers. These appear to be all triclinic, and in some slices show flow structure very perfectly. Where most numerous, they are also often arranged radially, or are clustered round augite grains.

(*c*) Grains and crystals of magnetite.

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* *Report of Progress Geological Survey of Victoria*, Part V., p. 117.

(*d*) Very numerous needles and prisms of apatite.

This ground-mass is decidedly of a micro-crystalline character, but in it are small porphyritic crystals of—

(*a*) Triclinic felspars, in which the brachypinacoid predominates, producing tabular crystals. I could not obtain any reliable optical measurements.

In some slices these felspars were much altered to aggregates of flakes, apparently micaceous. This was not the case in the rock sample which I selected for analysis.

(*b*) Crystals and crystalline grains, singly or in clusters, of an almost colourless augite. Twinning frequent, according to the ordinary law, composition face being $\infty \bar{P} \infty$ (100).

(*c*) Crystals of magnetite.

(*d*) Spaces filled by secondary products, usually quartz or agate, but also calcite, and more rarely the minute green siliceous amygdules which I have already mentioned in speaking of the Diabase porphyrite. Chloritic minerals (viridite) are rare, and, in fact, the principal pseudomorphs appear to be calcite after augite, and ferric hydrate after magnetite.

The miscroscopic examination of this rock shows many points in common between it and the Diabase porphyrite of the Snowy River, and strongly suggests that it is merely a somewhat different form of the same igneous rock.

In order to make further comparisons, I prepared slices from samples of an extremely hard and compact rock which underlies the Devonian limestone at the junction of the Buchan and Murendel rivers.

On examining it under the microscope, I foundits structure to be completely micro-crystalline, being composed of a perfect network of microscopic felspar prisms, filled in by augite grains and magnetite. In this ground-mass were a few larger triclinic felspars, and rather more numerous crystals of augite, so that, in fact, the structure of this rock approached the micro-porphyritic; the porphyritic mineral being mostly augite.

In this rock, a number of the augite crystals had been removed, and the spaces filled by brown iron ore, which is also common in the slice, and is often connected with remains of magnetite.

The following quantitative analysis is of the sample selected for examination. The indicative ratio of this rock is smaller than that of the Diabase porphyrite. In calcu-

lating it, I have, as before, disregarded the free silica as being extraneous and variable in amount. The microscopic examination showed that it is to be regarded as a finely crystalline form of Diabase, and the above ratio agrees well with that conclusion :—

DIABASE—MURENDEL MINE.

	Per cent.	Molecules.			Ratio.
$Si.O_2$	... 48·48	... 161·60	Acids, less free $Si.O_2$	=	3·760
Al_2O_3	... 14·57	... 28·29	R_2O_3	=	1·000
Fe_2O_3	... 11·68	... 14·60			
FeO	... 2·83	... 7·86	RO.	=	1·626
CaO	... 9·56	... 34.14			
Mg.O	... 5·55	... 27·75			
K_2O	... 1·77	... 3·77	R_2O	=	·784
Na_2O	... 3·33	... 10·74			
H_2O	... 1·72	... 19·11			
CO_2	... 1·27	... 5·78			
P_2O_5	... ·45	... ·63			
		101·21			

Indicative Ratio = 1·194 to 1.

Hygroscopic moisture ... ·85
Specific gravity ... 2·807

This analysis may be more readily calculated for mineral percentages than the former one, as being of a crystalline rather than a porphyritic rock. The CO_2 and P_2O_5 clearly indicate the amount of calcite and apatite respectively. In the absence of alterations to kaolin, serpentine, or chlorite, the whole of the H_2O probably belongs to the ferric hydrate; and the remainder of the Fe_2O_3 should indicate the magnetite. In fact, there remains, however, a small portion of Fe_2O_3 over, which may be either regarded as an analytical error, or as representing ferric oxide (hæmatite, ironglance), which has not been recognised under the microscope. The alkalis may be assigned wholly to the soda and potassa felspars, leaving the remainder of the Al_2O_3 as before, to give the amount of the lime felspar. The balance of the CaO, with the whole of the Mg O, together with a proportionate part of the Si O_2, should give the augite, leaving a small balance of Si O_2 for the free quartz and the agate recognised under the microscope. On this plan I have framed the following scheme :—

DIABASE.

	SiO_2.	Al_2O_3.	Fe_2O_3.	Fe. O.	Ca. O.	Mg. O.	K_2O.	Na_2O.	H_2O.	CO_2.	P_2O_5.		
Per cent, ..	48·48	14·57	11·68	2·83	9·56	5·55	1·77	3·33	1·72	1·27	·45	..	101·21
Molecules ..	161·60	28 29	14·60	7·86	34·14	27·75	3·77	10·74	19·11	5·78	·63	314·27	..
Calcite ..	..	..	..	..	5·78	..	..	..	..	5·78	..	11·56	2·89
Apatite ..	..	..	..	..	2·10	..	..	..	..	..	·63	2·73	1·04
Limnite ..	..	..	6·37	..	..	..	..	..	19·11	..	..	25·48	6·82
Magnetite ..	..	..	7·86	7·86	..	..	..	..	..	..	..	15·72	9·12
Hæmatite ..	..	..	·37	..	..	..	..	..	..	..	..	·37	·30
Potass Felspar. .	22·62	3·77	..	..	..	..	3·77	..	..	..	..	30·16	10·50
Soda Felspar ..	64·44	10·74	..	..	..	..	..	10·74	..	..	..	85·92	28·19
Lime Felspar ..	27·56	13·78	..	..	13·78	..	..	..	..	..	..	55·12	19·23
Augite ..	40·23	..	..	..	12·48	27·75	..	..	..	..	..	80·46	21·11
Free Silica ..	6·75	..	..	..	..	..	..	..	..	..	..	6·75	2·02
Totals ..	161·60	28·87	14·60	7·86	34·14	27·75	3·77	10·74	19·11	5·78	·63	314·27	101·32

The ratios between the minerals, as disclosed by this calculation of the analysis, are as follow :—

	Per cent.	Molecules.
Felspar	58·82 ...	173·52
Augite	21·05 ...	80·24
Magnetite	13·04 ...	19·64

or felspars, augite, magnetite, as nearly 9· 4· 1·.

This ratio indicates a Diabase rock in which the felspars are not so preponderating as in the Diabase porphyrite of the Snowy River. The ratios between the felspars are the following :—

Albite, orthoclase, anorthite, as 3· 1· 2·, nearly.

As there were no reliable measurements from which to form an opinion as to the probable character of the small porphyritic felspars, I can only follow the considerations which influenced me in the former case. If the larger felspars are regarded as normal andesine of the composition albite 1· to anorthite 1·, then there remain over potassa felspar and soda felspar in equal proportions, which may be regarded as a potassa-bearing albite, existing as the microscopic triclinic felspars of the groundmass.

There can be, it seems to me, no reasonable doubt that this rock, which at Murendel occurs as intrusive masses in the felsitic beds (Lower Buchan beds), is the same, under somewhat different structural conditions, as is found conformably underlying the Buchan limestones (Upper Buchan beds) at the Snowy River.

On the western side of the Murendel River, close adjoining the termination of the section which I have given, are the olivine-bearing igneous rocks, in which the adit of the Murendel-south Mine has been driven. I have not been able to find any natural sections in which the actual relations between these olivine-bearing rocks and the overlying marine limestones could be traced. It seemed to me useless to carry out a quantitative analysis of the former. They have undergone so much alteration that scarcely any points of comparison with those already analysed would remain. Their microscopic features I have described in the papers already quoted. For the present, it must remain undecided whether the olivine-bearing rocks form part of the great group of Diabase rocks of the neighbourhood, or are much altered basalts of tertiary ages,

or melaphyrs of older. I have at present no data to decide this question.*

I have shown reasons for believing that the intrusive igneous rocks at the Murendel, and along the track thence to the Snowy River, as well as the contemporaneous rocks at the Snowy River itself, are all varieties of Diabase. To this must be added similar rocks at Back Creek, and on the eastern side of the Buchan River, near that place. It is necessary to enquire now, what are the relations of these igneous rocks to the great group of formations, called the Buchan beds, and among which they are found ?

At Buchan, Murendel, Butcher's Creek, Rodger's Creek, the Snowy River, and Gellingall, the characteristics of these Buchan beds are always the same. I have found the group to consist invariably of two well-marked divisions.† A lower series (Lower Buchan beds) of from four hundred to five hundred feet in thickness, almost wholly of fragments of felsitic and, more rarely, sedimentary rocks, with interposed felsite sheets; the upper series (Upper Buchan beds), of from 750 to 1000 feet in thickness, consisting almost wholly of marine limestones, rich in remains of corals, mollusca, and placodermatous fish of Middle Devonian age. The exception to this completely calcareous nature is in the passage-beds at the base of the series, in which the felsitic and calcareous characters are commingled, decreasing as to the former in passing upwards, until, at heights varying from (say) ten to fifty feet, the beds are the purely marine limestones, characteristic of the Upper Buchan beds.

The two groups are not discordant to each other, the distinction being in the nature of the materials of which they are composed. In addition to the particulars relating to the contact of the Upper and Lower Buchan beds, which I have given in the previous papers quoted, I now give the following :—

I have found the contact of the limestone and fragmental beds to be well marked near the Murendel mine, and on tracing the beds further up the Murendel River, it became evident

* Whilst this paper has been going through the press, I have had an opportunity of again visiting this locality. A careful examination has satisfied me that the olivine-bearing rocks are, in fact, part of the same group which here generally and immediately underlies the marine limestones. Here, as elsewhere, the beds are some crystalline and some fragmental. I reserve fuller particulars for a future communication.

† *Progress Report Geological Survey of Victoria*, Part V., p. 117.

to me that the same contact continued well marked throughout. There are always more or less of passage-beds. The underlying felsitic beds are not, however, of the same character in all places. Near the Murendel Mine the upper bed of the lower series is distinctly composed of a mass of felsitic fragments, among which felspar particles are recognisable—therefore probably a tufa.* Some miles higher up the river the passage-beds rest upon a true quartz felsite. Intermediately, I found felsitic rocks of both kinds, and also of varieties of which I could not say, with any feeling of certainty whether they were originally fragmental or not. I have said that in tracing the course of the Murendel River upwards, it is also possible to trace with more or less distinctness the course of the felsitic beds on which the Upper Buchan beds (Buchan limestones) rest. It is seen that the latter have not only a general westerly dip, but also a marked undulation along the strike, thereby producing a number of secondary dips at right angles to the main dip, but of limited area and extent, forming a series of synclinals and anticlinals. The felsitic rocks, the passage-beds, and the lower of the marine limestones, therefore, alternately rise and fall below the level of the stream, which may be broadly stated to flow along the contact of the upper and lower beds. Thus there are usually on the western side high and precipitous limestone cliffs, showing at their base traces of the felsitic beds; while on the eastern side are almost wholly rugged hills of harsh and massive felsites.

On approaching that part of the valley known as the Pinnacles, where the river has formed a subterranean passage through the limestone hills, and only flows over the surface during floods, the felsites no longer have the well-marked, bedded, and fragmental character of those nearer the mine, but are to all appearance characteristic examples of a reddish or salmon-coloured quartz felsite.

In certain places I found it to have a ground-mass resembling a reddish felsite, studded with rather perfect dihexahedra of quartz. The rocks are then traversed by a few joints, dipping S. 70° W. at about 26°. The river has eroded during floods a channel in these hard and massive rocks, with smooth and almost polished sides, and with many huge "giant kettles." This is very favourable for the study

* Locally where the Diabase rocks occur the fragmental beds are either composed wholly of their fragments or of these mixed with felsitic materials.

of the rock structure. I found several places where there were many fragments of other kinds of felsites embedded. In one small area of about twelve feet in diameter I observed embedded angular fragments of red quartz felsite, fine grained grey felsite (felstone), compact grey felsite, and dark coloured, almost black, felsite. The fragments were some larger and some smaller than about an inch cube. I have made the following observations on a thin slice of this rock:—

It has a large proportion of ground-mass, in which is so large an amount of yellowish basis, that the slice remains very much obscured throughout when rotated between crossed nicols. It shows fluidal structure strongly. There are many minute granules of quartz in the ground-mass together with microscopic felspar prisms, which latter are almost invariably arranged with their longer axes parallel to the course of the flow. There is also a little iron ore (magnetite ?) in grains, and finally many dark brown, to almost black, long and somewhat ragged-edged microliths, which are otherwise undefinable. In this ground-mass are:—

(*a*) Quartz crystals, with either crystalline outlines or as fractured pieces. Sinuses of ground-mass penetrate them in the usual manner, or the ground-mass separates fractured parts. Fluid cavities are small and infrequent. The only inclusions I observed were portions of ground-mass and minute portion of slaggy-looking material.

(*b*) Felspars, some of which are orthoclase and some plagioclase. All have very imperfect outlines, more especially the former, as if partially refused after crystallisation. The triclinic felspars have all, so far as I could obtain measurements, low angles formed by the plane of vibration, namely, between 2° and 15°, and are, therefore, probably either albite or oligoclase. The felspars contain many minute green flakes, which may be a chloritic mineral.

(*c*) A few minerals having a long prismatic habit and a rhombic cross section. They are much altered to viridite and to ores of iron (magnetite ?). I was unable to observe any dichroic effects in the small portions having a pale green colour still remaining clear and translucent. The rhombic cross sections have the angles of amphibole, to which group I refer this mineral.

Finally, there are a few crystals of apatite, of which the greater number are included in the felspars.

The microscopic examination of this rock shows all the characteristic features of a quartz felsite, and I think that the most reasonable conclusion to arrive at is, that it represents a "lava flow" contemporaneous with the formation of those felsitic beds which occupy the same relative position to the limestones elsewhere, that this quartz felsite does at the place described. The numerous embedded fragments must in this case be regarded as having been taken up by the fluid lava. The full relations of this rock to the associated fragmental beds can only be ascertained by a more minute examination of the intervening parts of the Murendel valley than I could as yet make. I must, however, point out that I have observed and described a case at the Buchan River, near Mount Dawson, where I could distinctly trace the passage of a fragmental felsitic bed into completely compacted rocks, exactly resembling a quartz felsite in outward appearance. In that case I could not feel any doubt that the felsitic material had been regenerated by means of some form of metamorphism as a rock simulating a quartz felsite. In this present case, however, I cannot either feel any doubt that the rock I have just described is a true eruptive rock.

The Buchan beds, as I have here and elsewhere described them, rest as a whole upon a vast thickness of the still older Snowy River porphyries. These, which occupy at least an area of 500 square miles, are composed of felsitic rocks, such as massive quartz felsites (quartz porphyries) of a granitoid, or of a compact, or, in places, even a vesicular, character. A very large proportion consists of fragmental beds either more or less bedded, or being agglomerates, not only of the above felsitic rocks, but also of older sediments (silurian), or even of granite. The fragments are of all sizes, from dust up to many tons in weight. Felsite dykes are a feature in many places traversing them. The thickness of the Snowy River porphyries is not evident, as they extend from the summit of the table-land of Woolgulmerang, where they are best seen, down to the very water-level of the Snowy River, where the sections terminate—a depth of some 2000 feet.

The Snowy River porphyries are to all appearance younger than the Upper Silurian, and they are certainly older than the Middle Devonian Buchan beds which rest upon them. It is possible that they may represent the Lower Devonian formations which have hitherto not been recognised in Victoria. If so, it would probably have been a period of

volcanic and terrestrial conditions terminating in the general subsidence indicated by the transition from the Lower to the Upper Buchan beds.

The Diabase rocks which I have described in these notes, I find at Murendel to have penetrated the felsitic Lower Buchan beds; at the Back Creek, to underlie the calcareous Upper Buchan beds, with apparently passage-beds connecting the two; and at the Snowy River, to be clearly and unmistakably in this position as regards the same formation. It seems, therefore, unavoidable to arrive at the conclusion that the Diabases of the Buchan district represent volcanic rocks, which date from the period of time marked by the change of material which distinguishes the Lower from the Upper Buchan beds. In other words, they represent at places near Murendel the "necks," while at the Snowy River they represent the flows themselves.

In some previous notes on the interbedded volcanic rocks of the Snowy Bluff,* I came to the conclusion that as they appeared to have originally consisted of the minerals plagioclase, augite, magnetite, and very rarely a little olivine, with some traces of a basis, they were to be regarded as highly altered basalts, or having regard to their being of upper paleozoic age, melaphyrs. In studying the Diabase rocks of Buchan and the Snowy River, I observed many striking similarities of composition and structure to the above, and I again examined the thin slices I had prepared of the Snowy Bluff rocks, and compared them with those discussed in this paper. The results I may thus state :—

1. The geological age of the two groups is—Upper paleozoic, those of the Buchan district being Middle Devonian, whilst those of the Snowy Bluff, are probably Upper Devonian.

2. Both rocks, to judge from the least altered samples, were composed of the minerals plagioclase, augite, and magnetite. In those of the Snowy Bluff traces of olivine are so rare, occurring, so far as I have observed, in only one of the many interbedded sheets, that its presence may be said to be the exception, proving the rule of its absence. The olivine-bearing rocks of the Murendel may yet prove to belong to the Diabase group of that district, and so become a parallel to those of the Snowy Bluff.

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* *Progress Report*, *Geological Survey of Victoria*, Part III., p. 75.

3. The alterations which have taken place in the two groups of rocks are analogous to each other. There appears to have been more or less molecular decomposition and recomposition of the rock-forming minerals. The alteration products of the Snowy Bluff rocks have been silica and silicates, while those of the Buchan district have been silica, silicates, and also carbonates. This difference is only due to local conditions.

4. If olivine be regarded as an essential constituent of basalt, and as marking the distinction between that rock and augite-andesite, as well as between melaphyr and diabase, then this rock both of the Snowy Bluff and of the Buchan district would be referred to Diabase.